Microstrip-Excited Double-Slot Antennas as Elements for a 2.5 THz Imaging Array Camera: Equivalent Network Model and Design

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An ultimate goal of any sensor technology must be the ability to produce diffraction limited imaging at a specified wavelength. In the optical, UV, infrared, radio and now even at sonic wavelengths, imaging is commonplace. At millimeter and submillimeter-wavelengths (frequencies from 100 GHz – 3 THz) this goal is still a technologist's dream. In this presentation the authors discuss and numerically analyze a front-end antenna design which allows diffraction limited imaging, true heterodyne operation, and monolithic fabrication, with the goal of realizing a room temperature high sensitivity 2.5 THz camera.

Key properties of the proposed planar array antenna design are diffraction limited element spacing, minimal mutual coupling, linear polarization, symmetric radiation patterns, and a high overall RF coupling efficiency over a 5-10% frequency bandwidth. Heterodyne behavior, for greatly improved pixel sensitivity, is enabled by the integration of monolithic THz GaAs Schottky diodes and intermediate frequency (IF) removal lines and filters, with each of the antenna elements. Since the impedance properties of these diodes is not measurable at THz frequencies, nor can the devices be characterized by any existing physical models, matching the antennas to the dodes cannot be accomplished with a high degree of accuracy a priori. Thus the design has the additional constraint that it has to be tunable, i.e. it has to be possible to perform slight variations at the wafer level to alter, and ultimately tune out, the reactive field contributions arising from the parasitics of the diode and feed structure.

The proposed 2.5 THz heterodyne camera front-end is composed of a 10x10 array of double slot antennas printed on a 3 micron thick GaAs membrane which is suspended above a close spaced metallic reflector. The slots are excited from the underside of the membrane via coupled lines which terminate at the submicron Schottky diode. Capacitive filters printed along the lines block RF from traveling out while allowing the downconverted IF (near 1 GHz) to pass unobstructed. From the point of view of the electromagnetic design, significant difficulties must be overcome. In the first place, as in all practical arrays, the characterization of the mutual coupling between the close spaced elements is of great importance. Secondly there is a great need to model the very fine details of the antenna feed structure at these high frequencies, including the transition between the feed lines and the diode as well as the geometry of the diode itself. Both of these aspects make it difficult if not impossible to analyze the design based on brute force method of moments or finite difference tools. We have therefore subdivided the problem and developed independent characterizations of some key elements present in the array geometry. 1) The active impedance of each slot antenna pair is characterized, including the mutual coupling with neighbor elements. 2) The reactive energy stored in the slot itself due to its transmission line excitation is explicitly accounted for. 3) The connection of the feed line to the Schottky diode is characterized. The ensemble of the solution of these three problems constitutes the full equivalent network of the array front-end which can then be evaluated using a simple circuit CAD tool.

After developing the full equivalent network for the array, the detailed dimensions of the antenna and feed structures have been optimized with the aim of maximizing the power coupled into the diodes. It turns out that polarization purity, coupling efficiency over 70%, and rotationally symmetric beam patterns are achieved over a 6% relative bandwidth around 2.5 THz. These and other results will be shown during the presentation.